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1.	Your reference	597GB
2.	Patent application number *(The Patent Office will fill in this part)*	0316921.6 19 JUL 2003
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Renishaw plc New Mills Wotton-under-Edge Gloucestershire, GL12 8JR
	Patents ADP number *(if you know it)*	2691002
	If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4.	Title of the invention	Reader For A Scale Marking
5.	Name of your agent *(if you have one)*	R D Cavill et al
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Renishaw plc, Patent Department New Mills Wotton-under-Edge Gloucestershire GL12 8JR
	Patents ADP number *(if you know it)*	7908650001

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	–	–	–

		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	–	–

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	0
Description	8
Claim(s)	0
Abstract	0
Drawing(s)	4 + 4

10. If you are also filing any of the following, state how many against each item.

Priority documents	0
Translations of priority documents	0
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0
Request for preliminary examination and search *(Patents Form 9/77)*	0
Request for substantive examination *(Patents Form 10/77)*	0
Any other documents *(please specify)*	0

11. I/We request the grant of a patent on the basis of this application.

Signature Date 18.07.03

AGENT FOR THE APPLICANT

12. Name and daytime telephone number of person to contact in the United Kingdom — A Iles 01453 524524

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READER FOR A SCALE MARKING

The present invention relates to a detector for detecting a reference mark or the like, in particular but not exclusively during measurement operations which use a scale and a scale reader.

The detection of reference marks is disclosed in our prior patent publication no. PCT/GB02/00638, the disclosure of which is incorporated herein by reference.

Reference marks allow a reader to find its position and are usually provided separately to periodic scale marks which provide an incremental signal to the reader for determining displacement. A reference mark could be anything that is recognisable by the reader. In practice a pattern is used because it is simple to produce and is more reliable, producing fewer false readings. When a pattern is used the reader will have a similar pattern so that when the mark and reader align a stronger signal is provided by the reader.

Combined reference and scale marks have been used commercially. In such instances the reference mark may be formed by a pattern of missing bits of the scale. The incremental signal from the periodic scale is read over a portion of the scale large enough to compensate for missing bits of the scale.

In order to improve accuracy known scale readers have employed two detectors e.g. photodiodes, usually called split detectors, to read a scale. The two photodiodes have been offset one relative to the other in the

direction of measurement by a small amount. When this configuration has been used the output of one photodiode lags behind (or is in front of) the other. A known technique is to produce a zero crossing output (detailed below) from the two photodiodes which improves detection accuracy.

The invention provides a reference mark reader having a patterned array of detectors for detecting a reference mark on a measurement scale wherein each of the detectors has an output, two or more of the detector outputs are summed to provide a first summed output and others of the detector outputs are summed to provide a second summed output, and the second summed output is subtracted from the first summed output.

In one preferred form the array of detector comprises two sets of detectors, however, there are drawbacks to using two sets of detectors: there is an increased cost; alignment of the two sets is difficult during manufacture; and misalignment between the reader and the reference mark is a problem during use.

The present invention provides also a reference mark reader having a single patterned array of detectors and a zero crossing output.

In this way a zero crossing output can be obtained from a single row of detectors.

The detectors may be photodiodes or a photodiode block. The first and second summed outputs may be subtracted by means of a difference amplifier. The outputs of the detectors may each be converted into digital form and

summed digitally.

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figs 1a and b show a reference mark reader arrangement according to the invention;

Figs 2a,b and c show another reference mark reader arrangement according to the invention;

Fig 3 shows an electrical schematic diagram of the components used in the reader shown in Figs 2a,b and c;

Figs 4,5,6 and 7 show alternative reference mark reader arrangements.

Fig 1a shows a novel arrangement of a reference mark reader 20 and a reference mark rm incorporated into an incremental scale 10.

In this arrangement a scale 10 has periodic markings of alternating transparent 12 and opaque 14 areas, e.g. chrome on glass. These markings are used in a conventional way to produce a signal indicative of displacement, using a conventional reader (not shown) adjacent the reference mark detector 20. In this arrangement a scale can move in the direction of arrow x and, in practice, its opposite direction also. For simplicity travel in the x direction only is described.

Incorporated into the periodic scale markings 12 and 14 is a reference mark rm. In this example the mark is 7 periods long. The reference mark could be completely separate from the incremental scale in which case any size of pattern could be used. The reference mark reader 20 has a point light source 22, light from which propagates through the transparent areas 12 and onto

rows of detectors A and B. Each row of detectors is formed from 7 photodiodes 1-7. The light will fall with little effect on the detectors as the scale is moved relative to the detectors. The reference mark has a pattern 1100101 where "1" represents a transparent area 12 and "0" represents an opaque area 14. Therefore, detectors 1,2,5 and 7 in each row only are monitored, which corresponds to the illuminated detectors when the reference mark 1100101 coincides with the corresponding pattern formed by those monitored detectors.

When the reference mark coincides with each detector, rather than substantially ineffectual light falling on those detectors, each detector is fully illuminated and a sudden increase in output V_A and V_B is effected.

Detector rows A and B are staggered by one detector width in this instance, so signal peaks V_A and V_B are staggered also. To improve accuracy signal V_B is subtracted from signal V_A at difference amplifier 24 to give an overall output signal V_{OUT}. It will be noted that V_{OUT} crosses zero at a distinct point and this zero-crossing can be used to give accurate positional information.

In this embodiment a mask can be placed over the detectors and all detectors can be monitored. This modification will achieve the same results as the arrangement illustrated. Alternatively, the unmonitored detectors 3,4 and 6 could be left out altogether.

Whilst the arrangement shown in Figs 1a and 1b is

satisfactory, it could be improved. Figs 2a,b and c illustrate an improved embodiment of the invention.

The components used in Figs 2a,b and c are similar to those illustrated in Figs 1a and b, however, only one row of detectors 20' is used in Figs 2a,b and c. The reference mark 1100101 is used again but the way in which the corresponding detectors are monitored is different. The reference mark pattern is written in the second row of the table illustrated in Fig 2c. The next row in this table has the same pattern displaced one place to the left (it could be more than one place and could be displaced to the right). The two rows are subtracted one column at a time and the result is given in the lowest row. This result dictates the pattern of the detectors. Now, a "1" detector (i.e. detectors 3,6 and 8) is connected to output A and a "-1" detector (i.e. detectors 1,5 and 7) is connected to output B. The resultant output of these connections when the 1100101 reference mark is detected is the outputs V_A and V_B. When the outputs are subtracted a zero-crossing signal V_{OUT} is obtained again.

Since only one single row of detectors is used in this embodiment the reader is less susceptible to yaw misalignment and is cheaper to produce.

Fig 3 shows a simplified electrical schematic diagram of one way in which the signals from the detectors 20' of Figs 2a and b can be processed. The same scheme could be used for the arrangement shown in Figs 1a and b also. Photodetector diodes D1 to D8 are shown. Diodes D3,D6 and D8 are connected to the input of an amplifier 26A for turning their current outputs into a

voltage V_A. Diodes D1,D5 and D7 are likewise connected to an amplifier 26B. The outputs of the amplifiers 26A and 26B are connected to the input of difference amplifier 24 which subtracts V_B from V_A to produce an output signal V_{OUT}. Diodes D2 and D4 are not used and are connected to 0V.

The amplitude of the V_{OUT} signal is used in this instance to activate a further circuit (not shown) which produces a signal when V_{OUT} crosses zero.

In addition to the difference amplifier 24 a summing amplifier 28 is shown. This amplifier sums the voltages V_A and V_B to produce a voltage VC_{OUT}. V_A and V_B will be at a maximum when all the respective photodiodes are illuminated i.e. when a solid block of "1"s (in this instance) is encountered by the detector. VC_{OUT} can be used to detect control marks on the scale e.g. end stops. Other values of VC_{OUT} e.g. zero,½,¾ of maximum can be used to indicate other control marks.

Fig 4 shows an alternative arrangement for processing the signals produced by the detectors 20'. Voltage signals V_A and V_B are fed into two respective analogue-to-digital converters (A-D) 30A and 30B. These A-Ds in turn feed a microprocessor 34 which gives a reference pulse output. The microprocessor might be used to convert the voltage signals V_A and V_B into digital form without the need for the A-Ds 30A and 30B.

Figs 5,6 and 7 show alternative configurations of detector 20 and scale 10. In Fig 5 a reflective scale 10 is used and a light source 22 is to one side of the detector block 20. The reference mark could be

reflective and the scale background non-reflective or vice versa. The light 22 could be in the middle of the block 20.

Fig 6 shows a collimated light source producing light which passes through a transparent reference mark on scale 10. Fig 7 shows a diffuse light source 28 producing light which passes through a reference mark on scale 10 and an imaging device such as pinhole, slit or lens 26. From the imaging device the light propagates to the detector 20.

In Figs 5,6 and 7 the same detector arrangement as described above may be used.

Many variants and modifications to the embodiments described and illustrated will be apparent. The reference mark is illustrated as being incorporated into an incremental scale. However, it is possible that a separate reference mark may be provided and the invention need not be used with an incremental scale. The reader may be moved whilst the scale is stationary or vice versa. Both may move relative to each other. The invention is described with reference to light and a light source. The light could be a point source e.g. a laser diode, an area source e.g. an LED, diffuse light e.g. an LED array or ambient light. The light used could be convergent, divergent, collimated or diffuse. The light may not be visible, it could be infra-red light or some other part of the electromagnetic spectrum. The invention could be practised with detectors other than light detectors e.g. magnetic detectors for use with a magnetic reference mark may be employed. A patterned reference

mark having a pattern 1100101 is illustrated but any recognisable pattern could be used. The pattern need not extend in a linear manner as shown but could be 2-dimensional. In practice a 24 bit series of "1"s and "0"s representing light transmissive/reflective, and non-transmissive/non-reflective parts of a mark has proven satisfactory. One example of such a series is 110101010110100100110011.

Fig 1a

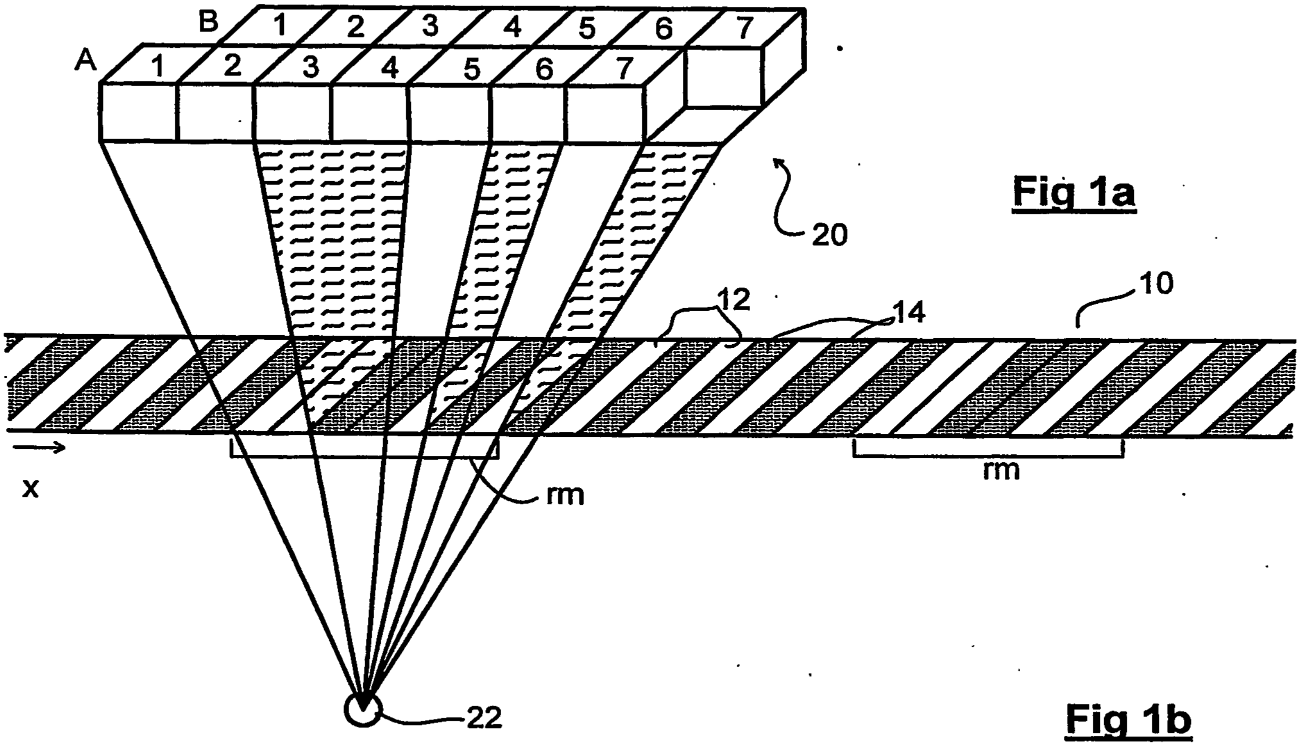
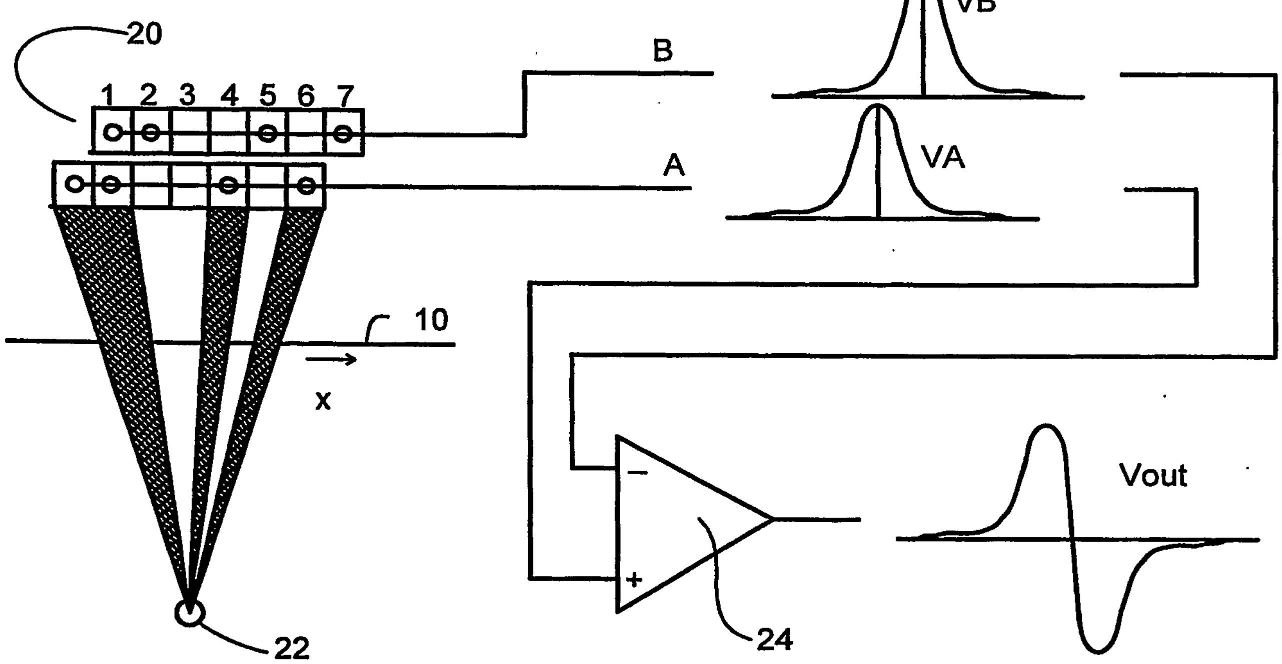

B
1
2
3
4
5
6
7
A
1
2
3
4
5
6
7
20
10
12
14
x
rm
rm
22

Fig 1b


20
1 2 3 4 5 6 7
B
VB
A
VA
10
x
22
–
+
24
Vout

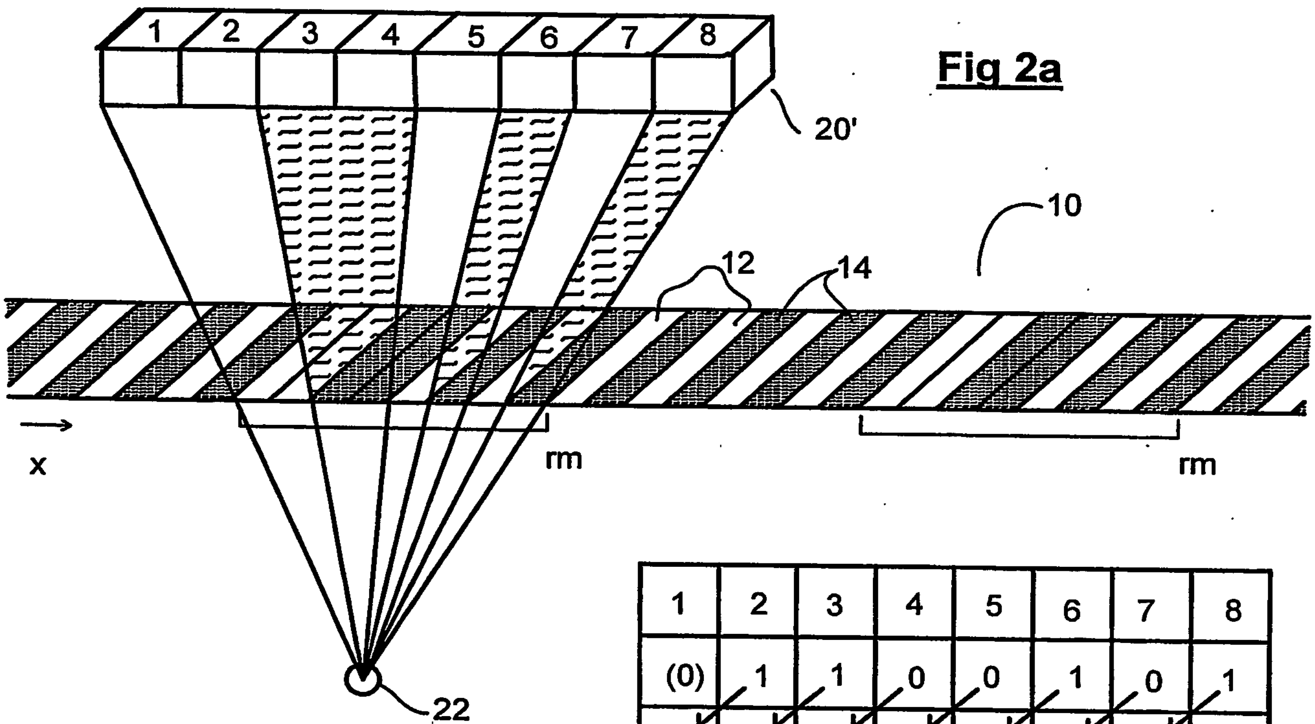
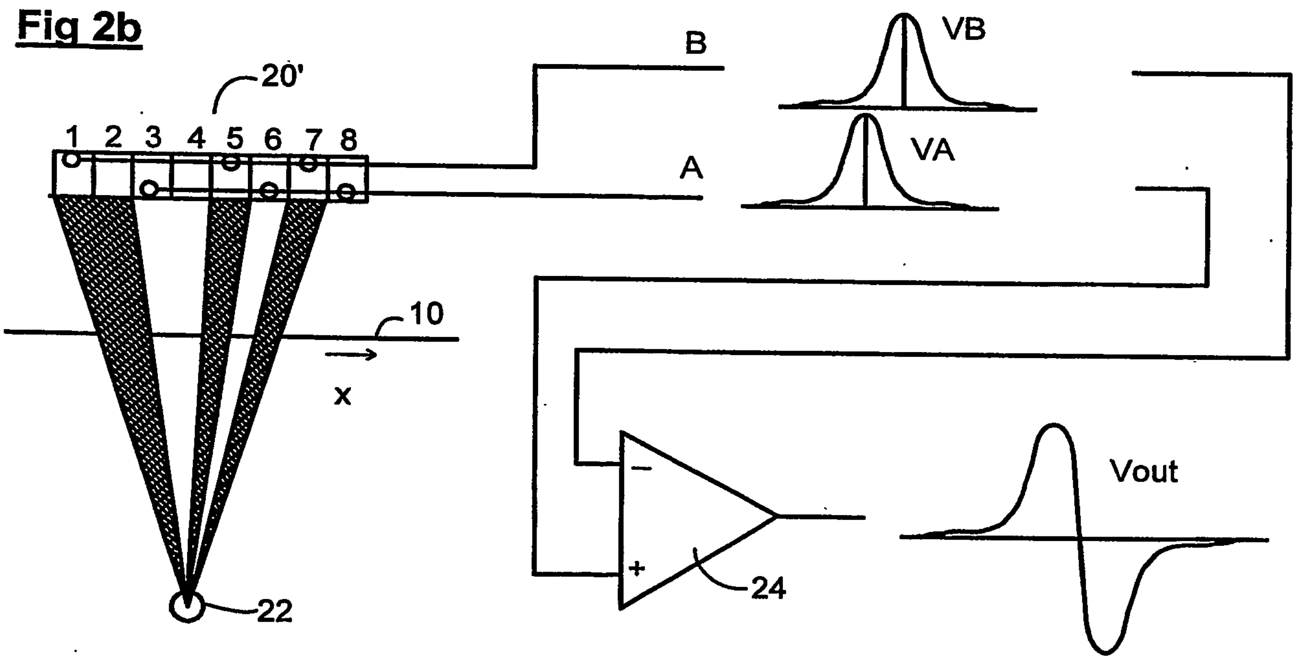


Fig 2a

1	2	3	4	5	6	7	8
(0)	1	1	0	0	1	0	1
1	1	0	0	1	0	1	(0)
-1	0	1	0	-1	1	-1	1

Fig 2c

Fig 2b



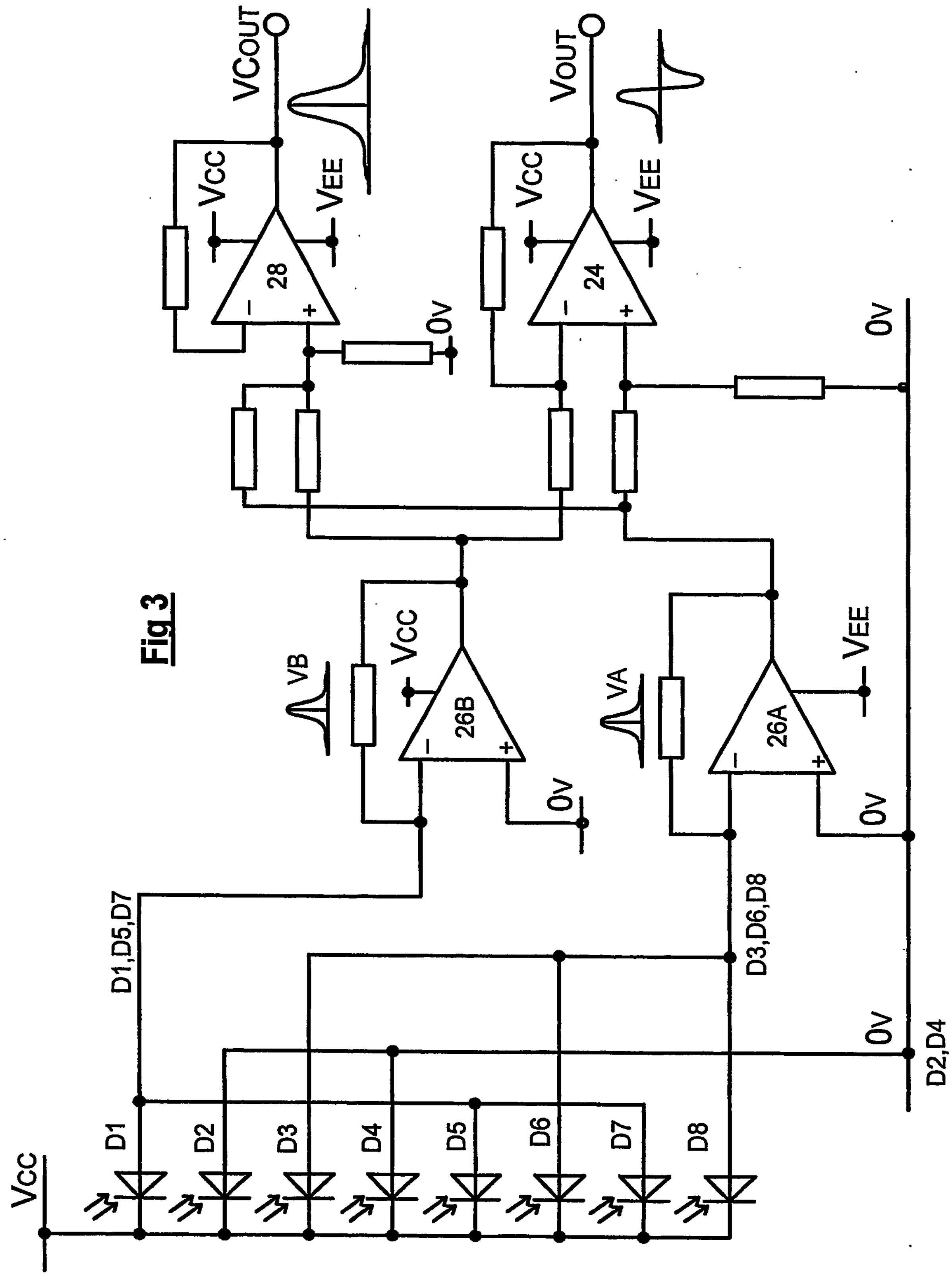

VCOUT
VCC
VEE
28
0V
VOUT
VCC
VEE
24
0V
VB
VCC
26B
0V
VA
VEE
26A
0V
D1,D5,D7
D3,D6,D8
0V
D2,D4
VCC
D1
D2
D3
D4
D5
D6
D7
D8

Fig 3

Fig 4

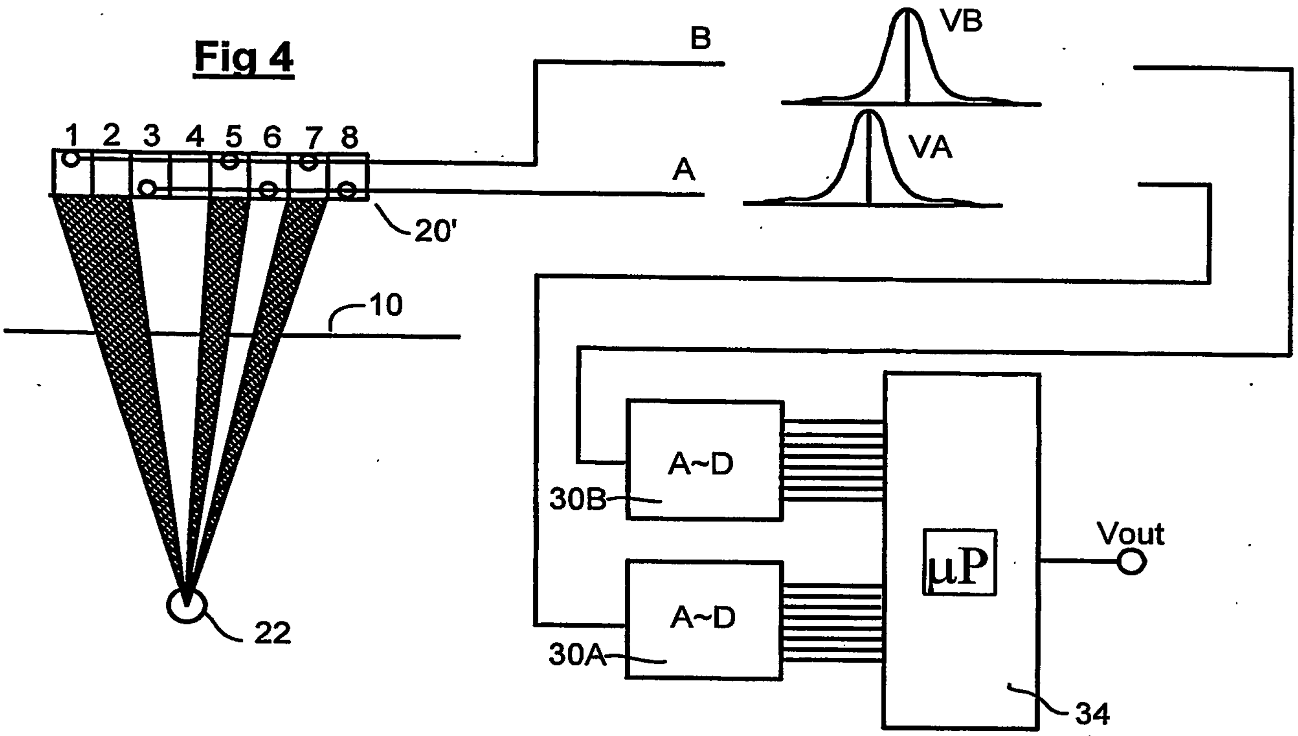


Fig 5

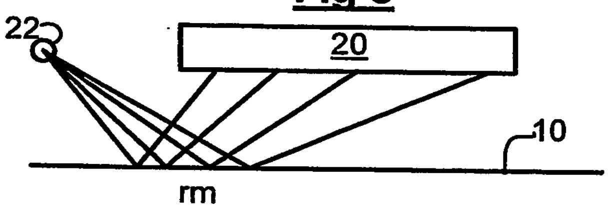


Fig 6

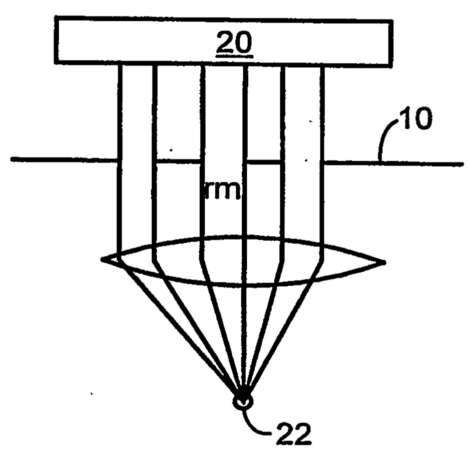


Fig 7